Flywheel Battery: From a Physicist's Idea to the Energy Marketplace

The flywheel battery developed at LLNL is now being fabricated and shipped to users by Trinity Flywheel Power.

Our flywheel battery has traveled a successful, and sometimes unanticipated, route from initial laboratory development to the marketplace. Along the way, this energy storage system has benefited from scientific vision and persistence, from diverse technical capabilities at LLNL, from industrial partnering, and from commercial developments in the materials used.

Today, under license from LLNL, Trinity Flywheel is manufacturing workable flywheel batteries in two sizes, with power ratings from 50 to 350 kW (the power capacity depends on how fast the stored energy is withdrawn). These are being used for power quality and backup DC power and, in a transportable form, to store energy for pulsed-power applications.

Trinity has used LLNL's prototype flywheel battery and performed extensive product engineering and manufacturability testing to develop the commercial product.

How It Works

The flywheel (or electromechanical) battery is a high-tech version of an ancient concept: using a rotating wheel to store kinetic energy, as in a potter's wheel. In this case, the energy is stored in a rotor made of carbon fiber material and spinning about 40,000–50,000 rpm. To avoid problems with stress and delamination, the rotor material is graded from fiberglass at the inner core to carbon fibers in the outer portion.

The rotor is integrated with a generator motor that incorporates a special array of permanent magnets—a Halbach array—to perform the charging and discharging functions. (The Halbach array was originally developed in the 1980s by a physicist at Lawrence Berkeley National Laboratory for use in particle accelerators.) The flywheel is stabilized by bearings and encased in a steel vacuum vessel to reduce friction.

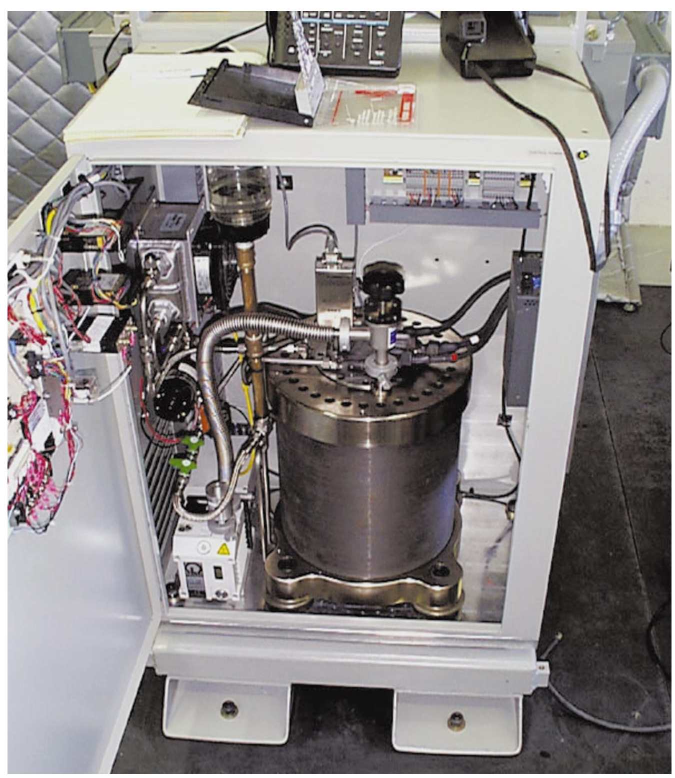
The flywheel operates with greater than 90% energy recovery efficiency (kWh out vs. kWh in) and—compared to the amount of energy stored—is much lighter than conventional lead-acid batteries. A modular approach allows multiple units to be combined for greater energy storage.

Applications

- Standby power
- High-quality uninterruptible power
- Hybrid-electric vehicles

How It All Began

Our flywheel concept originated in the early 1970s with LLNL physicist Dick Post, who suggested to his son Stephen, an electric car buff, that flywheels might



A flywheel for power-quality use by industry.

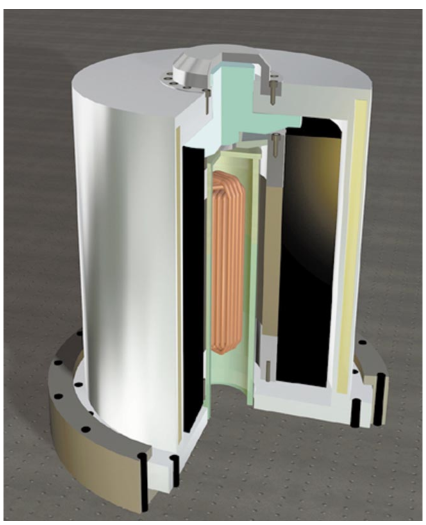
be a good way to store energy in electric vehicles. The two Posts, father and son, wrote a *Scientific American* article in 1973 recommending that flywheels be made of composite materials instead of metal and presenting a new approach to rotor design. At the time, the Posts envisioned flywheels both for electric vehicles and to help utilities manage peak power demand.

With the energy crisis of the 1970s, LLNL and other national laboratories began serious research into flywheels and the use of composite materials, but funding for that research ended in the mid-1980s.

Then, in the early 1990s, three factors led LLNL to resume flywheel research using internal funding: new integrated designs had been conceived, graphite composite material of very high strength became widely available at acceptable cost, and California and other states were mandating the sale of zero-emission vehicles. Trinity Flywheel and another industrial partner soon joined in funding LLNL's research.

The work drew upon LLNL expertise in physics, materials science, magnets, and mechanical and electrical design. Prototypes and a bench-scale version were built, tested, and improved upon. In 1994 the technology was licensed to Trinity for manufacturing.

Today, one major application for the flywheel is to provide the power conditioning and power quality (that is, free from interruptions and glitches) that is needed for computers and other sensitive electronic equipment essential to modern life (and far more prevalent now than when Dick Post initially began thinking about flywheels.) Post still thinks that flywheels will eventually be used in vehicles, because they are especially appropriate for hybrid-electric vehicles where they could provide acceleration power and recoup kinetic energy now lost in braking. He also envisions flywheels someday providing energy storage and uninterruptible power for individual homes, but he thinks that those flywheels will be of higher storage capacity than the current ones and will be made of fiberglass, which is less expensive than carbon fibers.



Energy is stored in the spinning rotor of carbon fiber material (shown in black in this image).

Looking to the Future

Development and improvements continue. Better carbon composite materials are being commercially developed—for a variety of applications, including golf club shafts and tennis rackets—that have increased ability to withstand pressure, and the use of such material could increase the energy density in flywheels.

LLNL and Trinity are also continuing the development of passive magnetic bearings to replace the current mechanical bearings. Passive magnetic bearings will reduce friction, have a longer life, and not require lubrication. ("Active" magnetic bearings exist that require external electronics and electric power, but these "passive" bearings would be self-contained and need no external energy source.) These bearings, like the flywheel's generator-motor, will incorporate Halbach magnet arrays to effect stable levitation.

Such passive magnetic bearings would be a new class of bearing / suspension systems, not just for flywheel batteries but for other high-speed rotating machinery, such as electric motors. The bearings would be more energy-efficient than present bearings and would not require lubrication or maintenance for the life of the equipment.

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